Fuels of the future

The world needs energy more than ever before. This means we need a sustainable system to meet these growing needs while addressing CO_2 emissions and the overall impact on the environment.

Hydrogen is a solution that can provide sustainable, efficient, and affordable energy to the world. scale. However, the shipping fee is expensive.

Hydrogen

Hydrogen is not only the most important element in the universe. It can also play an important role in the energy mix of the future, from cars to trains, from trucks to ships, to electricity generation and to heating gardens. This is because it is a clean, clean fuel that only releases water when burned or oxidized.

Currently, about half of the world's hydrogen production comes from gas (methane) used in the fertilizers, metals and aerospace industries. But the process of removing hydrogen from carbon monoxide also produces about 10 tons of carbon dioxide for every ton of hydrogen produced. That's why we need to find a more sustainable way.

Blue hydrogen: a key element of the circular carbon economy

For over a decade, we have been exploring potential technologies for producing high-purity hydrogen from hydrocarbons, including thermal neutral conversion (TNR) and catalysts to convert diesel to hydrogen. Our ultimate goal is to create "blue" hydrogen that extracts valuable fuel while capturing all CO2 emissions.

Hydrogen and carbon dioxide are produced when methane is burned, but the difference with blue hydrogen is that we capture and reuse, eliminate or reuse carbon dioxide emissions. This is all part of our circular economy vision.

We are now able to extract about 80-
85% of the energy from hydrocarbons to hydrogen gas and then use the CO_2 captured using two new technologies. The first involves injecting one of our oil reservoirs to improve oil recovery, while the other involves converting waste carbon dioxide into chemicals such as methanol for use. An additional amount of carbon dioxide can also be safely stored deep underground.

Reducing the cost of transportation

Making hydrogen blue is only half the solution. The next problem we have to tackle is how to store the reserve fuel and get it to where it's needed.

Hydrogen is a very light molecule. It may be liquid, but it must be stored at -
254 °C, making it difficult and expensive to transport, especially over long distances. The solution is to convert hydrogen into a substance already commercially available worldwide: ammonia.

Compared to hydrogen, the transportation of liquid ammonia is more convenient, efficient and effective in terms of temperature and temperature.

When blue ammonia reaches its target, it can be converted to blue hydrogen or used directly as fuel in gas turbines for clean electricity generation.

The world's first blue ammonia shipment

In
2020 we completed one of our most ambitious trials to date, an integrated demonstration covering all hydrocarbon resources in partnership with SABIC and the Japan Energy Industry Institute (IEEJ).

We will be able to reap the fruits of this special cooperation in August 2020, when we send 40 tons of high-quality blue ammonia to Japan.

Blue ammonia itself is being transported to our home in Japan; here, 20% of the ammonia is processed in existing power plants with coal and gas alike. According to the IEEJ, the pilot project is one of many that will help Japan achieve its ultimate goal of be coming a decarbonised society, where up to 10 percent of its electricity can be generated from blue ammonia in a day.

Synthetic fuels

Hydrogen and fuel cell technologies also have potential for the future of transportation. In 2019, Aramco established its first hydrogen refueling station in Saudi Arabia, while countries such as Japan, China and South Korea are investing in hydrogen refueling stations and infrastructure. The growing demand for hydrogen helps justify the importance of our ability to transport hydrogen around the world at low cost.

Catalyzing new pathways to cleaner fuels

Many challenges will continue into the future, such as working with our international partners to develop ways to convert most hydrocarbon energy to hydrogen and to improve the overall process for the manufacture of electric and hydrogen cars and chains.

However, it is clear that converting natural gas to blue hydrogen could be the key to producing affordable, reliable and sustainable clean energy for everyone.

Hydrogen is the simplest substance. A hydrogen atom has only one proton and one electron. Still the most important thing in the universe. Despite its simplicity and abundance, hydrogen does not appear on earth as a gas; always combines with other elements. For example, water is a mixture of hydrogen and oxygen (H2O).

Hydrogen is also found in many organic compounds, particularly hydrocarbons that make up most of our fuels, such as gasoline, natural gas, methanol and propane. Hydrogen can be separated from hydrocarbons by heating it in a process called reforming. Currently, most of the hydrogen is produced from natural gas. The current can also be used to split water into oxygen and hydrogen. This process is called electrolysis. Some algae and bacteria use sunlight as energy, even releasing hydrogen gas under certain conditions.

The energy of hydrogen is high and the engine that burns hydrogen does not cause pollution. NASA has been using liquid hydrogen to propel space shuttles and other rockets into orbit since the 1970s. Hydrogen fuel cells power the space shuttle's electrical system, turning it into a clean product (clean water) for the crew to drink.

Hydrogen Fuel Cells

Gases combine hydrogen and oxygen to produce electricity, heat and water. Fuel cells are often compared to batteries. Both convert energy from chemical reactions into usable electricity. However, when the fuel cell (hydrogen) is supplied, the fuel cell generates electricity and does not lose its value.

Fuel cells are useful tools that can be used to heat buildings and provide energy, as well as as power generators to run cars. Fuel cells work best with pure hydrogen. But fuels such as natural gas, methanol and even gasoline can be converted to produce the hydrogen needed for fuel cells. Some fuel cells can also run directly on methanol without using a converter.

In the future, hydrogen may become the main energy along with electricity. Electrical equipment carries electricity in usable form and delivers it to consumers. Renewable energies such as sun and wind cannot always produce energy. But they can produce electricity and hydrogen that can be stored until needed. Hydrogen can also be transported (like electricity) wherever it is needed.

Understanding Fuel Cells and Their Role in the Green Energy Revolution

The support and energy of the future should be designed to meet the challenges of society such as climate change, the need for more energy and mobility. The energy needs of the world population are developing. Oil can be an important part of the competition.

As hydrogen becomes a storage medium at all energies, the potential of fuel cell technology is complex. Strong arguments for the use and distribution of these devices are reliability, efficiency and the ability to use renewable energy.

Thanks to their modular design, gas turbines can be easily adjusted to suit the product needed, and their low maintenance and operating costs also make them attractive. In addition, fuel cell technology is ready for commercialization and suitable for commercial use. The fast-growing industry presents huge growth opportunities for zero-emission fuel cell technology.

How Fuel Cells Work

A gas engine works differently from an internal combustion engine. They convert fossil fuels directly into electricity that can be used to generate more electricity. This conversion is more efficient than internal combustion engines because the intermediate thermomechanical requirements of the conventional heat exchanger (heater) are eliminated.

The best thing happens when fuel hydrogen can be regenerated, as it allows both pollution and climate change pollution to be reduced to zero. In this way, fuel cells have the potential to be an important technology in terms of decarbonized propulsion and energy.

Cryogenic Proton Exchange Membrane Fuel Cells or PEMs (sometimes called Polymer Electrolyte Membrane Fuel Cells) currently represent the most suitable technology for developing and growing the Rolls-Royce powertrain portfolio. The low temperature cell has a high energy density, which allows the equipment to be upgraded from even a small device.

Cryogenic fuel cells operate up to 100°C with little danger to equipment and personnel, while hot fuel cells reach temperatures between 250°C and 1.000°C. Compared to other types, PEMs have excellent performance characteristics, allowing them to respond to changes in energy demand within seconds. One of the advantages of PEM fuel is its excellent electrical properties, especially in a part. They mostly use hydrogen fuel; however, they can operate with a variety of fuels such as methanol, diesel or natural gas. This is done by converting the gas into hydrogen using an efficient reforming process. This provides many applications for proton exchange membrane fuel cells.

Proton exchange membrane fuel cell is the first cell to electrochemically react fuel and oxidant (usually air) to produce electricity and fuel. It works silently without too much vibration. Like batteries, fuel cells produce DC voltage. But unlike batteries, fuel cells constantly require fuel and oxidant.

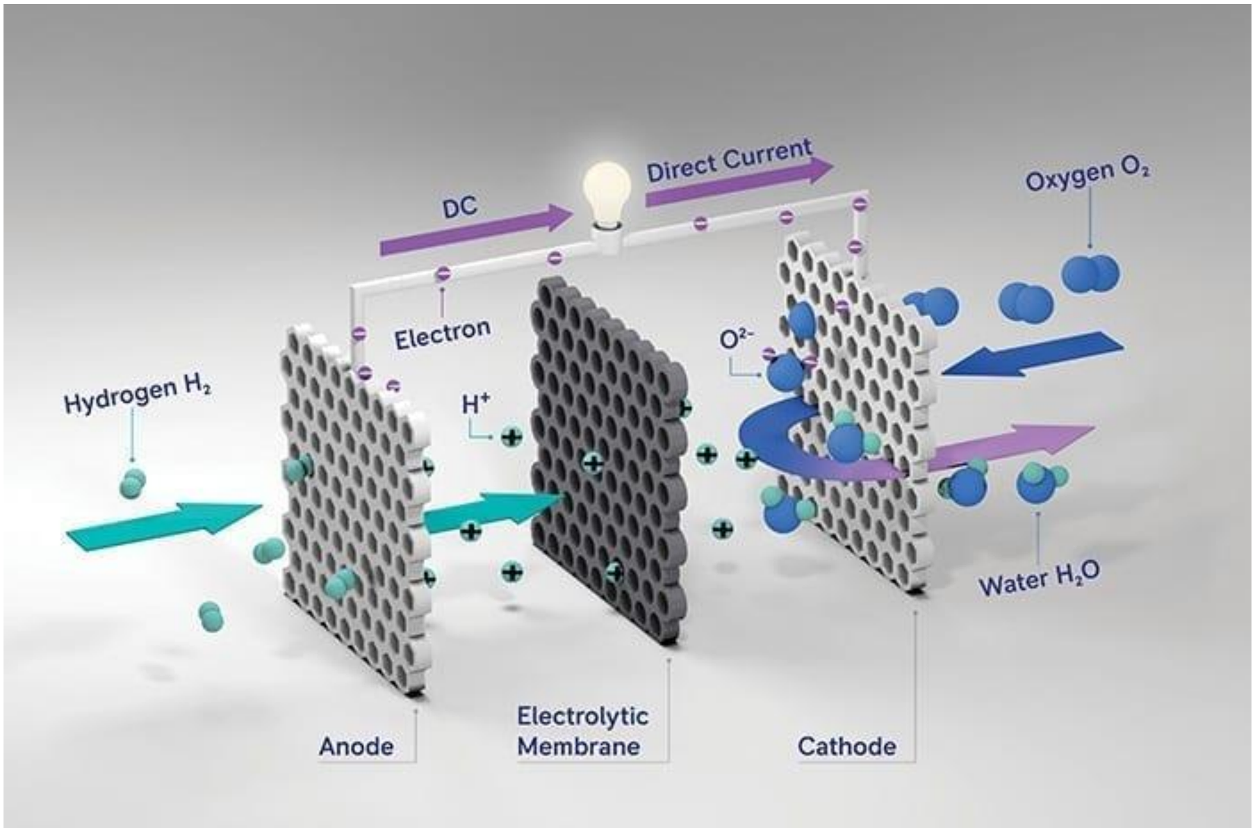

Figure 1: The electrical components of the electronic device include the anode, cathode and electrolyte membrane.

When a PEM fuel cell is used, chemical processing occurs between the electrodes (anode and cathode) and good ions (protons) moves from the anode to the cathode, electrons are made from the outside of the anode towards the cathode via an electrical conductor. The product of this process is electricity, which can be extracted and used. The electrodes are coated with a platinum or palladium catalyst and separated by an electrolyte. Without a catalyst, hydrogen and oxygen do not react, producing heat and electricity. The electrolyte has an ion-
conducting membrane that is essentially permeable to protons and impermeable to electrons.

Improving Upon Well Established Technology

The name "Polymer Electrolyte Membrane Fuel Cell" indicates that the membrane is the main part of the fuel cell. It is usually made of plastic, similar to Teflon. A water-saturated polymer membrane acts as an electrolyte, allowing only protons of positively charged hydrogen nuclei to pass from the anode to the cathode. The water content of the membrane required for ion conduction limits the operating temperature to a maximum of 100°C. In recent years, the price of important metals such as platinum, which needs catalysts, has decreased. This has significantly reduced costs and is also the focus of development efforts.

PEM fuel cells are ideal for Rolls-
Royce powertrain applications due to their energy efficiency, high scalability, modular design capabilities and ease of manufacture. For example, fuel cells can be built directly into batteries that use electricity or electricity. The battery achieves high electrical efficiency (approximately 50%) and high current and is also highly efficient. This situation necessitates not only the use of fixed electricity (such as an emergency generator or without electricity), but also the fulfillment of all mobile phone needs.

To increase power, today's gas engines are sometimes equipped with air compressors or even electric turbochargers. Like an internal combustion engine, a compressor or turbocharger pumps air into the engine at a pressure of 2 to 3 bar. The voltage of many people can be increased by connecting the throttle in series to form a group. The group can also be connected to the scale for better performance. This increases the value of the current product to several times the amount generated by the link.

Rolls-
Royce Power Systems draws on years of expertise and experience in developing and applying fuel cell technology. Between 1999 and 2011, 26 high temperature fuel cell systems Molten Carbonate Fuel Cells (MCFCs) were installed and successfully applied in various applications. The combination of electricity and high power is widely used in many industrial and sanitary processes. The system has been operated for approximately 22,000 hours on average, and all performance data and results have been recorded and analyzed. While the market and the general process of that time did not support all products, now all lights are starting to mass market PEM fuel cells as another source of energy propulsion.

Fuel Cell Applications

Their properties mean that PEM fuel cells are well suited for many applications today running internal combustion engines. Among other things, fuel cells can play an important role in zero carbon information, demand response and ship propulsion.

Data Centers

It is part of security-oriented infrastructure worldwide, including centers, hospitals, airports and telecommunication centres. Many data centers use diesel generators for emergency power. Combustion of fossil fuels (diesel) inevitably results in gaseous emissions. If the fuel cell is used as backup power, the only output will be heat and exhaust gas. Mechanical stress is reduced because there are no moving parts in the fuel cell system.

Fuel cells are also more efficient than electric motors. Another advantage is that fuel cell systems can be easily expanded. More modules mean more power, and the power grid can be easily added later and grows with the data center.

Demand Response

Renewable energy requires high flexibility. Where wind or solar power is too much, electricity can be used to produce hydrogen via electrolysis and store it without limiting production. When needed, this energy can be given back in the form of electricity for a short time by using gas. Load management or "demand response" operation using smart grids can be an important factor in transforming energy into sustainable production methods.

The solution using PEM fuel cells with batteries is best in terms of stability of the grid and buffering of power peaks. Customers can use the system to meet their needs even if renewable energy generation is low. PEM fuel cell generators can be connected to local generators or microgrids.

Ship propulsion. Alternative propulsion systems are attractive and suitable not only for cars and trucks, but also for ships. The shipping industry accounts for 2% to 3% of the world's carbon dioxide emissions, and this share is expected to increase by 2050 as global trade increases. Onboard fuel cell systems have many advantages. Fuel cell marine propulsion systems are appreciated not only for their safety and environmental friendliness, but also for their high passenger capacity and high modularity. They are quiet, odorless and vibration free. This emission-free propulsion system allows the boat to be used in oceans, lakes and water areas where some other systems are questioned due to its environmental impact.

Electric drive motor consists of many parts. At the heart of the body is the fuel cell that converts hydrogen into electricity. This electricity is sent from ship electricity to small consumers "at home", as well as large consumers such as generators powering generators and cranes. On-
board power distribution systems also often contain electronic devices such as lithium-ion batteries for temporary power storage. Such batteries allow a work time for energy production and use, opening the operating hours of individual products to maximum performance. This requires smart energy management to manage individual properties.

Fuel Cell Outlook

Gas engine is getting more attention due to pollution emissions and air pollution. Fuel cells, low-cost, zero-
carbon energy production and use of renewable energy for heating purposes are more efficient than other systems, making them attractive for many applications. Even today, fuel cells are used to provide mobile power to land vehicles and ships, as well as to generate sufficient energy at stand-alone facilities. One of the advantages of hydrogen-powered fuel cells is that CO2 emissions from both ships and power plants are reduced to zero when green hydrogen is used.

Fuel Cell Technology

The development of brain fuel dates back to the early 1800s, with Sir William Grove being named as explorer in 1839. For the past century, scientists have been trying to develop the fuel that the brain uses from a variety of fuels and electrolytes. Further work in the first half of the 20th century eventually laid the foundation for the machine to be used in the Gemini and Apollo space flights. However, it was not until 1959 that Francis T. Bacon successfully worked on the first fuel cell.

Proton exchange membrane fuel cells were first used by NASA in the 1960s as part of the Gemini program and were used in seven missions. Fuel cells that use pure oxygen and hydrogen as the reacting gases are small, expensive, and non-
commercial. NASA's interest led to further developments such as electric power in 1973. Fuel cell research has continued since then and fuel cells have been used successfully in a variety of applications.

Fig. 2: Various PEMFC stacks

Advantages of Fuel Cells

Fuel cell systems are often compared to internal combustion engines and batteries and have advantages and disadvantages.

Fuel cell systems have the following advantages:

- Fuel cell systems work with pure hydrogen without creating pollution, the only source is pure water and heat. When operating on a hydrogen-rich alternative fuel mixture, some harmful emissions are produced, although less than emissions from combustion engines running on traditional fossil fuels. To be fair, an internal combustion engine burning a mixture of hydrogen and air will produce very little pollution, mostly from the breakdown of the lubricating oil.
- Fuel cell systems work with more energy than heat systems. Heating systems such as internal combustion engines and turbines convert chemical energy into

heat by mixing and using heat to do work. The ideal (or "Carnot") thermodynamic efficiency of a heat engine is called:

$$Efficiency_{MAX} = 1 - \frac{T_2}{T_1}$$

Electric (cold) gas expands more (in ^{0}R or K) and hot oil has a higher temperature.

Therefore, since the temperature of the outlet cannot theoretically be lower than the temperature, the temperature can be increased by any amount to achieve the desired result.

However, in real heating systems, the maximum temperature is limited by material considerations. In addition, in internal combustion engines, the inlet temperature is the engine operating temperature at the ignition temperature.

As the fuel cell does not use combustion, its efficiency is independent of the maximum operating temperature. Thus, the efficiency of the heat transfer stage (actual combustion reaction rather than actual combustion reaction) can be greatly improved. Electrochemical reaction efficiency is not the same as overall system efficiency. Performance characteristics of fuel cells compared to other power generation systems are shown in Figure 3.

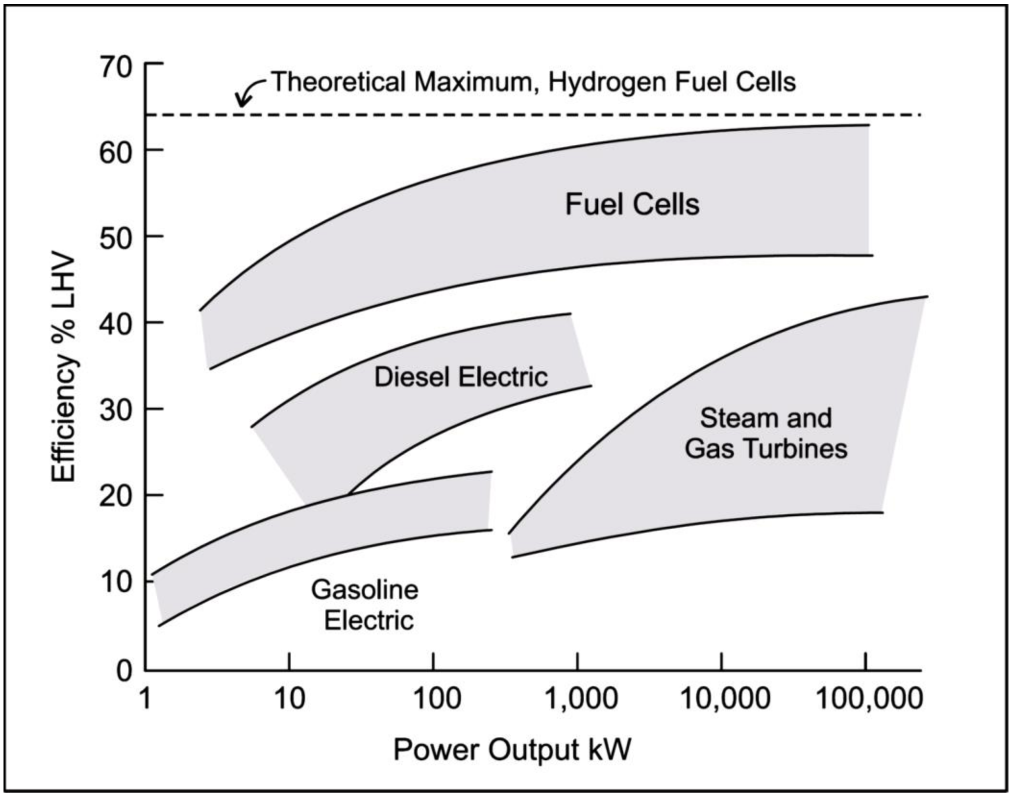

Figure 3: Comparison of Energy Production Efficiency

- In addition to the special thermal efficiency of fuel cells, the batteries are higher than heating systems, the efficiency does not decrease. The heating system works best when operating at design speed and exhibits a reduction in the operating speed of the load.

Like batteries, fuel cells perform better at partial loads than at full load and have less variability in overall operation. Fuel cells are modular in structure and have the same functionality regardless of size. But the modifiers work less efficiently on the load, so when combined with fuel cells the overall performance of the hull suffers.

- Fuel cells have the following advantages. Fuel cells, like batteries, are solid-state devices that respond quickly to changes in load. But gas turbines are mostly mechanical devices and each has its own time to respond to changes in demand

Nevertheless, gas engines running on pure hydrogen will have the perfect response. However, the gas engine running on both the modification and the card modification may run slowly, especially when using the mechanical modification.

- When fuel cells are used as a source of electricity generation, they require less energy than heating systems. Fossil fuels, when used as an energy-generating material, require the same conversion time, although their specific conversions are different.

There is an effect of energy loss in every energy conversion; therefore, the less the conversion, the better the efficiency. Therefore, fuel cells are more suitable for applications that require more electrical energy than conventional electronic products. The power conversion comparison of gas, battery and heat engine is shown in Figure 4.

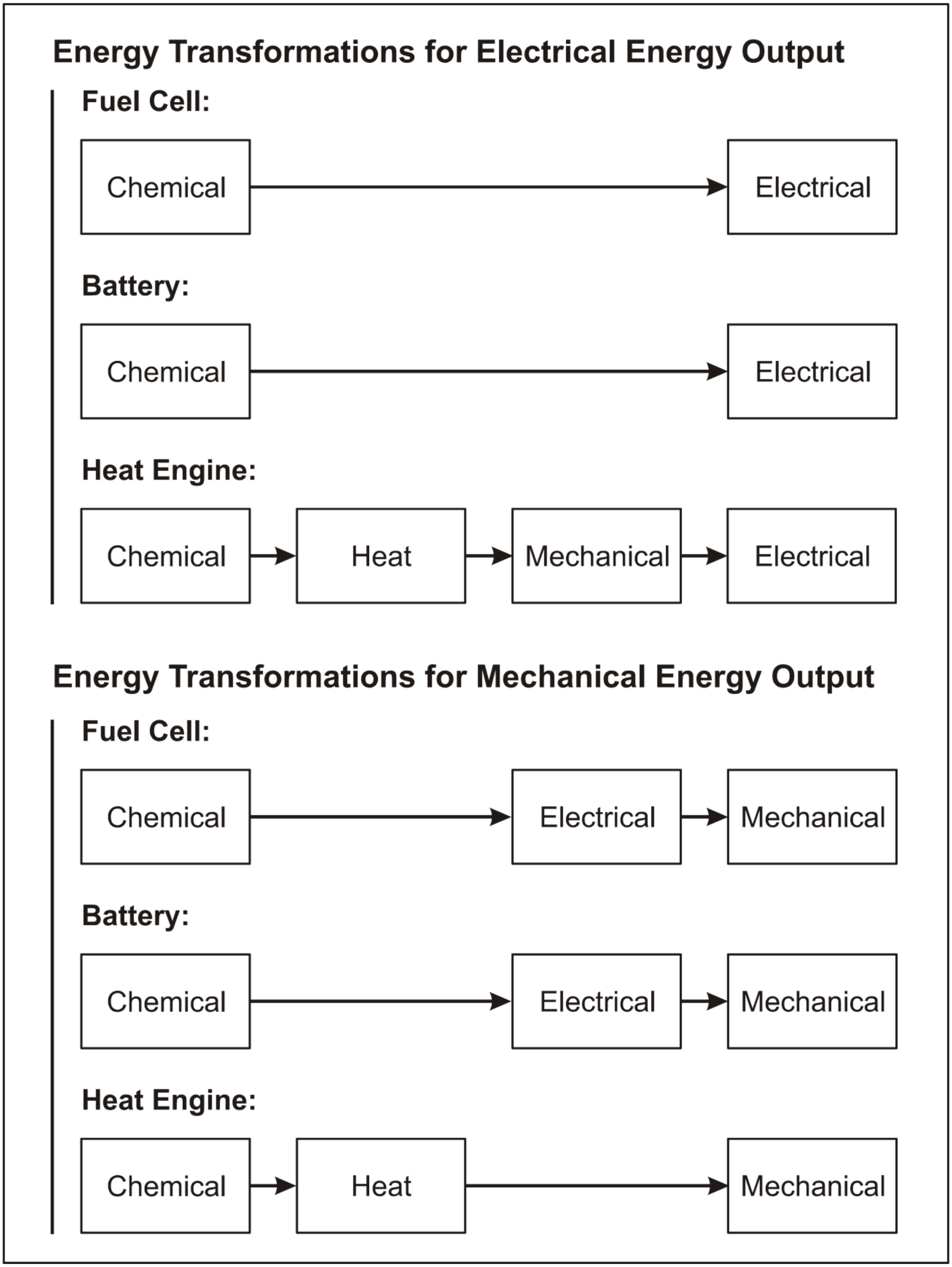
Energy Transformations for Electrical Energy Output
Fuel Cell:
Chemical
Electrical
Battery:
Chemical
Electrical
Heat Engine:
Chemical
Heat
Mechanical
Electrical
Energy Transformations for Mechanical Energy Output
Fuel Cell:
Chemical
Electrical
Mechanical
Battery:
Chemical
Electrical
Mechanical
Heat Engine:
Chemical
Heat
Mechanical

Figure 4: Comparative Energy Transformations

Fuel cell systems have the following disadvantages:

- Ironically, hydrogen is very beneficial for the environment when used in fuel cells, but its biggest disadvantage is that it is difficult to manufacture and store. The current production process is expensive and labor-intensive and often results in the use of fossil fuels. An efficient hydrogen system has not yet been developed.

Gas hydrogen storage systems are large and heavy to meet the low volumetric energy density of hydrogen. Liquid hydrogen storage systems are smaller and lighter but must operate at high temperatures. Alternatively, storage and simple solutions at the expense of some environmental benefits, if the hydrogen is stored as a hydrocarbon or alcohol and released by reorganizing the board on demand.

- Fuel cells need pure, non-polluting fuel. These pollutants include sulfur and carbon compounds, as well as residual fuel (depending on the type of fuel cell) that can affect the fuel cell catalyst, making it less efficient. None of these pollutants prevent combustion in the combustion engine.
- Fuel cells for automobile use often require the use of platinum catalysts to facilitate the energy generation reaction. Platinum is a rare and expensive metal.
- There should be no ice in the fuel cell. Fuel cells produce pure water during the electrical reaction, and fuel cells are generally suitable for use in vehicles using wet fuel. Water remaining in the fuel can cause irreversible swell damage if allowed to freeze. The gas generator generates enough electricity to prevent freezing at high temperatures during operation, but when turned off in cold weather, the gas must be kept warm or any residual water removed before freezing. This often requires taking the car to a heated area or using a local heater.
- Fuel cells using proton exchange products should not be dried during use and should be kept moist during storage. Attempting to start or operate the fuel cell in a dry environment may damage the membrane.
- Fuel cells need support and control systems. Fuel cells themselves are state-of-the-art equipment, but not the machinery required to support their operation. Pay attention to the need for compressed air; this requires high speed compressors

that put a huge load on the entire system. System complexity increases considerably when the gas generator works together with the on-board rectifier.

- Fuel cell systems are very heavy. The fuel cell itself is not very heavy, but the weight, support and fuel tank of the fuel cell are now more compared to the hybrid generator. The process of including the replacement of the board of directors is more serious. Although battery-powered systems require less support equipment, gas-powered systems are generally lighter than their battery-powered counterparts. The weight of the system will tend to decrease when technology is used. Despite the heavy weight, models with the available fuel system have shown that the system can be installed in the vehicle.
- Fuel cell is a new technology. As with any new technology, reducing cost, weight and size while ensuring reliability and longevity remain key engineering goals.

Applications

Fuel cells are modular in nature and therefore suitable for many applications, from large fixed power units to small portable power units.

Stationary Powerplants

The application of power plants has been encountered in many experimental projects using various fuel technologies over the years. The largest power plant to date is Ballard Power Generation Systems, a 250 kW natural gas-fired proton exchange membrane fuel cell power plant currently operating in various parts of the world. Although small compared to conventional power plants, 250 kW is sufficient to assist isolated communities or to provide emergency backup power for important facilities such as hospitals.

Fixed power plants are clear candidates that run on conventional fuels such as natural gas that can be sent to the power plant and replaced on site. In small applications, overall size and warm-up times are less of an issue. In addition to high performance, low emissions and good fuel response, stationary applications amplify the full benefits of energy resources by producing large amounts of hot water and waste heat that can be used directly in surrounding communities system.

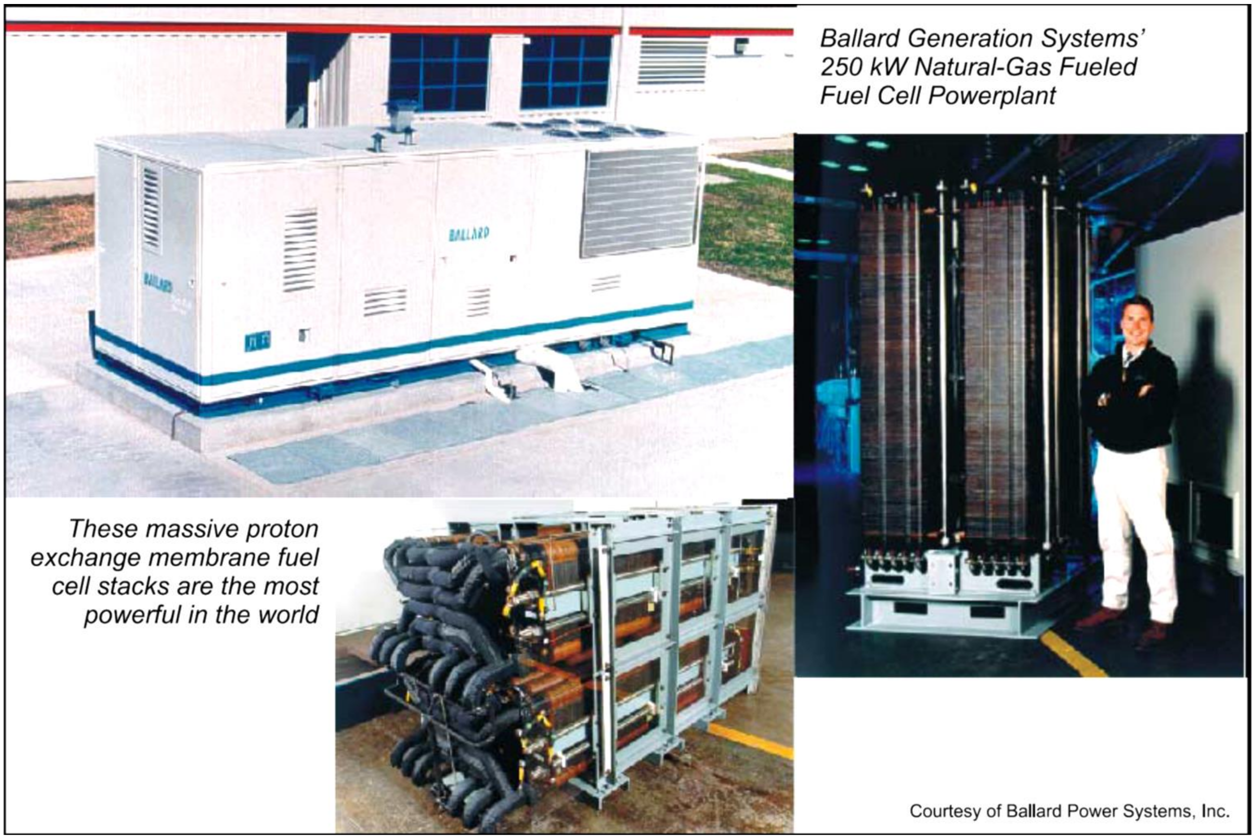

Figure 5: Station power plant

Submarines

Fuel cell systems are attractive for military submarine applications due to their low noise and infrared signature. In many ways, fuel cells are replacing the battery packs currently used to power many ships on board. As with fixed energy products, there are also hot water products for domestic use. Prototypes using pure reagents and on-board modifications have been found in recent years.

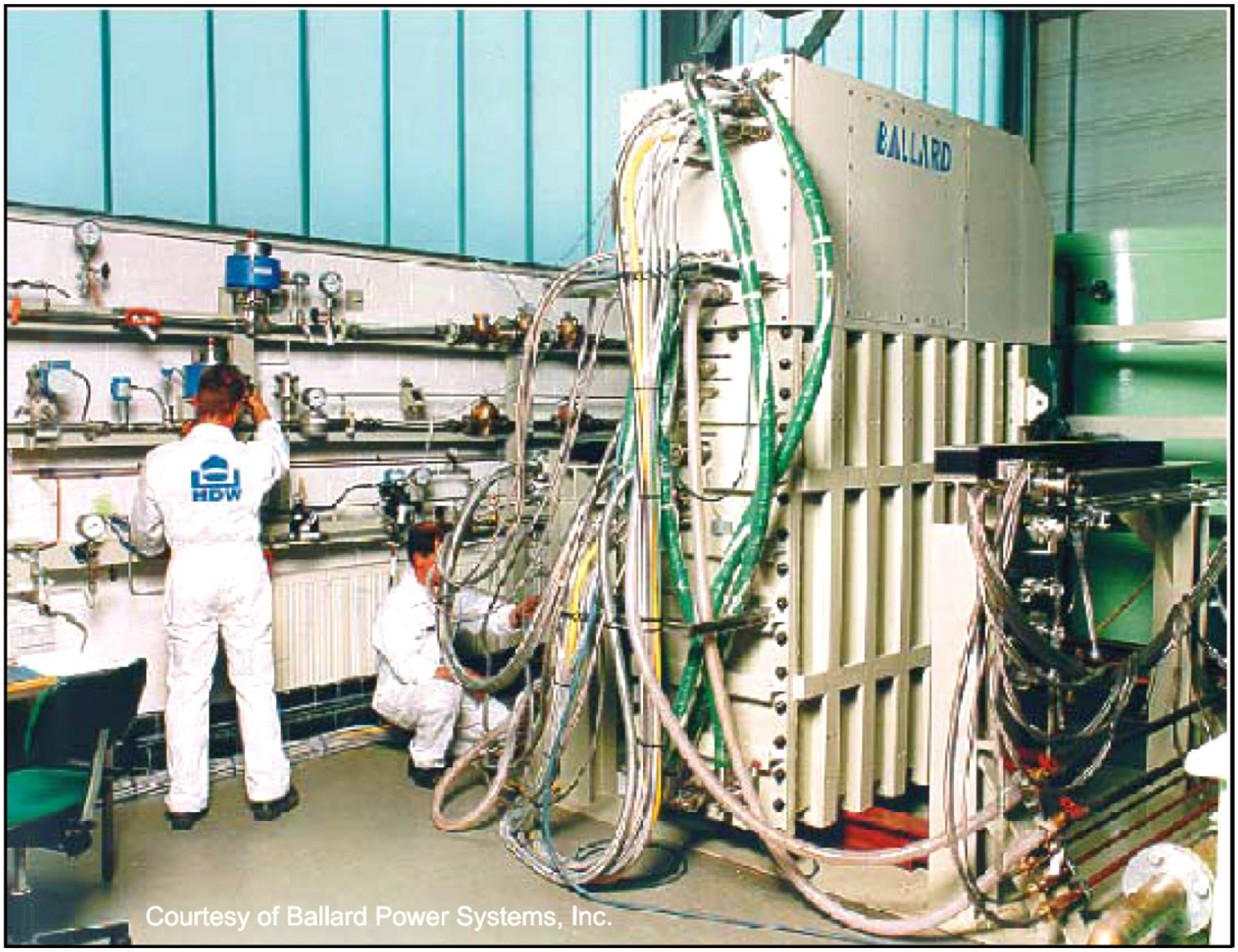

Figure 6: Military Submarine Applications

Buses

The submarine is by far the most commercial of all fuel applications. XCELLSiS Fuel Cell Engines Inc. It has completed a demonstration project showing three buses per operation over two years in Vancouver, British Columbia and Chicago, Illinois, and a one-
year trial run in Palm Springs, California. More buses will be available in Europe and other parts of the world soon. All these buses run on pure water stored as high-energy gas; other demonstration vehicles run on liquid fuel and use a modified onboard system.

Busses are the principle of introducing fuel cell technology into the transport sector for several reasons: they provide a large platform for equipment and fuel storage, they can be recovered at central stations and are operated by trained personnel.

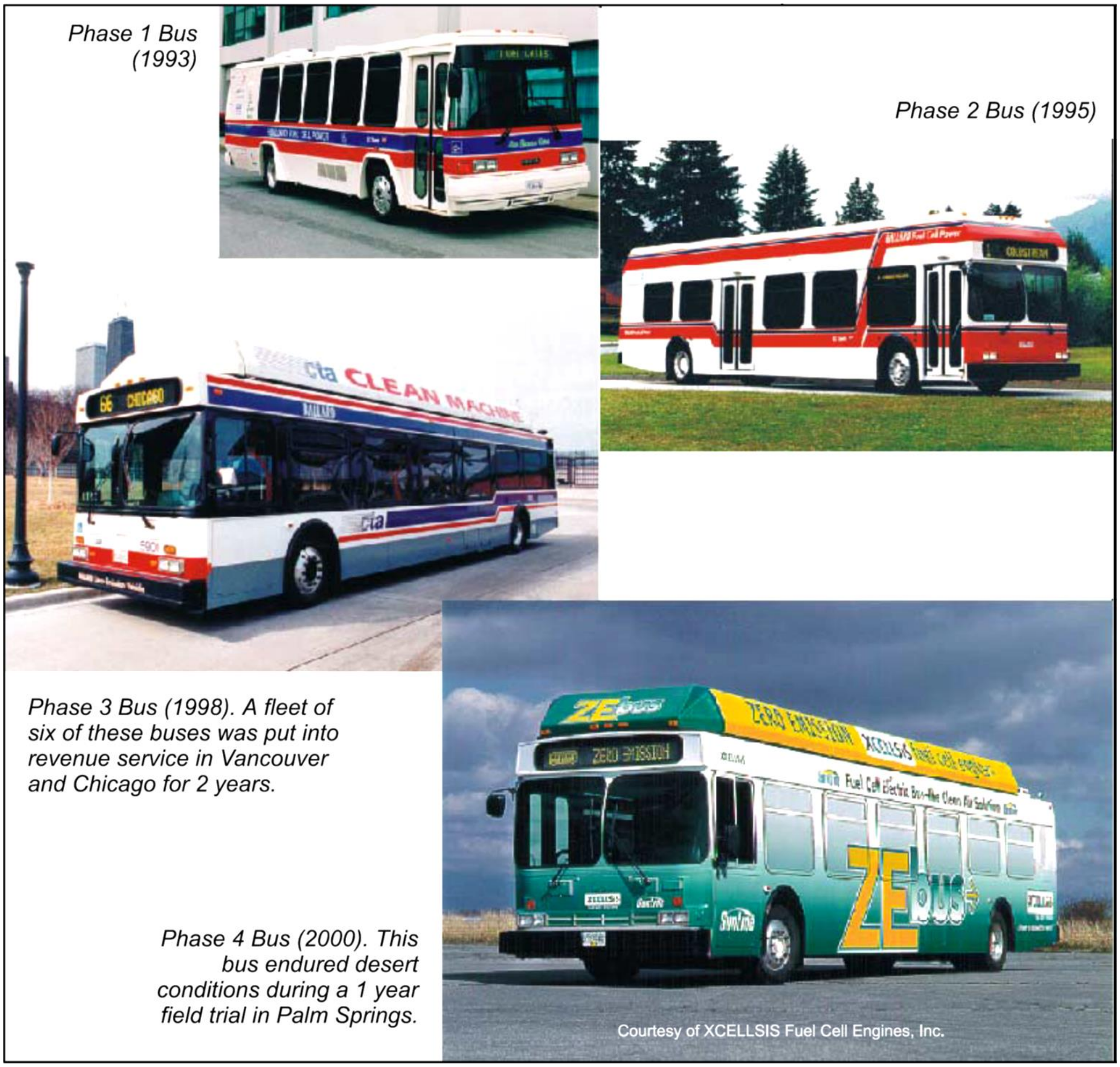

Figure 7: Buses are the most commercial of all electric fuel applications

Cars

As volumes are shared globally, cars represent the end market for the gas company. While cars are a major contributor to the production of fuel cells, they also cause some of the biggest problems for the economy as they are a major source of pollution. These challenges include its small size, the large amount of gas it needs, and the continued public interest. In addition, quality and reliability expectations are high, while value expectations are low.

Many major automobile companies are involved in the production of gasoline vehicles, including DaimlerChrysler, Ford, General Motors, Nissan, Mazda, Subaru, Toyota, Honda and Hyundai. Some of these companies have developed fuel cell vehicle models with or without rechargeable batteries, using pure (gas or liquid) hydrogen or alternative fuels.

The absence of existing hydrogen systems is a major obstacle to the use of the fuel in vehicles. For this purpose, many models now use in-vehicle conversions containing methanol as fuel, but gasoline is still being researched.

While this alleviates some of the gasoline availability and storage issues, it increases the amount of hardware that must be installed in the vehicle (thus increasing cost and complexity) and introduces converter-related management and efficiency issues. Of course, implementing reforms did not eliminate pollution and did little or nothing to reduce dependence on fossil fuels.

Many automobile manufacturers have promised to bring gasoline cars to the market in the early 2000s. These vehicles are likely to appear in fleet operations to minimize fuel and maintenance issues.

Figure 8: Automotive represents the end market for fuel cells.

Portable Power Systems

Portable fuel cell systems can be used in many applications currently relying on batteries. Commercial units currently provide up to 1.2 kW (4100 Btuh).

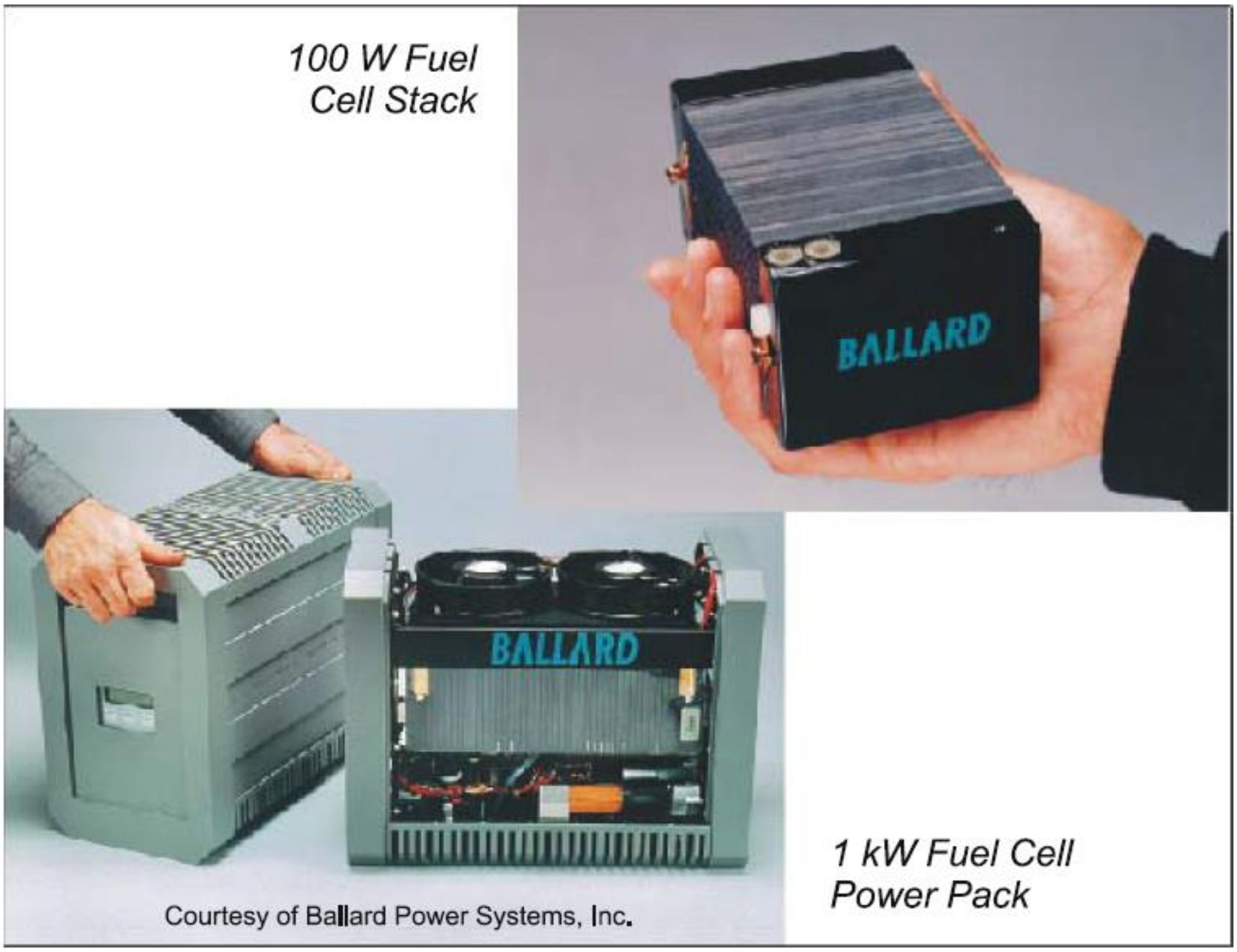

Figure 9: Portable Fuel Cell System standard thermal or mechanical.

Principle of Operation

When the fuel chemically reacts with the oxygen in the air, energy is released. In an internal combustion engine, the reaction occurs violently and energy is released as heat; some of it can be used to do good work by pushing the pistons. In a fuel cell, the reaction occurs electrochemically and energy is released as a combination of low voltage DC power and heat. When heat is lost or used for other purposes, electricity can be used directly to perform important tasks.

Electrochemical reactions in galvanic batteries form the basis of the conversion of chemical energy into electrical energy. All types of electricity are main cells and batteries. In an electrolytic cell, by contrast, electrical energy is converted into chemical energy, such as by electrolysis or electroplating.

Fuel Cells

An important feature of the fuel cell is that the current charge determines the amount of hydrogen and oxygen. In the process of use, the oil can be used for various electrical products. In a fuel cell, the fuel and oxidant gases form the anode and cathode, respectively. Therefore, the physical structure of the electric fuel is one in which the fuel is transferred to both sides of the electrolyte by the flow of water. Electrolyte is the difference between different types of fuel cells. Different electrolytes form different ions.

Electrolytes can be liquid or solid; some work at low temperatures. Low-burn fuels usually require a high-quality electrode (usually platinum) to support the electrode reaction, while high-burn fuels do not. Most fuel cells suitable for use in vehicles use low-energy materials that produce hydrogen ions, as shown in Figure 10.

In principle, fuel cells can work with different types of fuel and oxidants. Hydrogen has long been considered the most efficient fuel for power generation due to its higher electrical conductivity than other fuels such as hydrocarbons or alcohol. Even fuel cells that run directly on non-hydrogen fuels tend to produce hydrogen and other products first before the reaction occurs. Oxygen is an obvious choice of oxidant due to its high reactivity and abundance in the atmosphere.

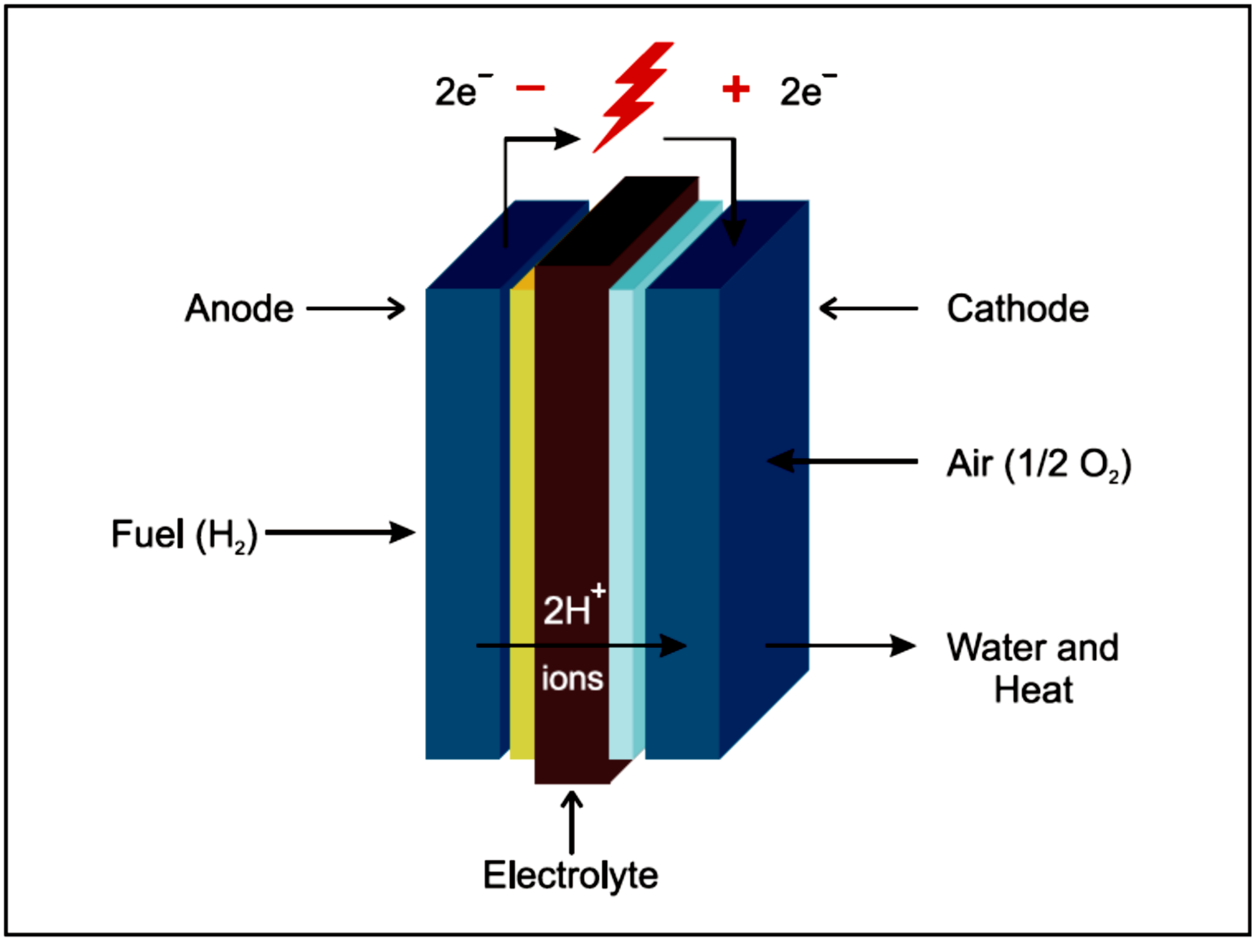

Figure 10: Low Temperature Electrolyte Produces Hydrogen Ions

Types of Fuel Cells

Fuel cell types differ depending on the type of electrolyte used. The type of electrolyte determines the operating temperature, and the operating temperature of different types is very different.

High temperature fuel cells operate at temperatures above 600 °C (1100 ºF). This heat allows the conversion of light hydrocarbon fuels, such as the conversion of methane to hydrogen and carbon in the presence of water. This reaction always takes place at the anode of the nickel catalyst as long as there is sufficient heat. This is the main part of the transfer process.

Internal modifications eliminate the need for a separate oil system and allow the use of oils other than pure water. These significant benefits lead to a 15% increase in overall performance. In the second electrochemical reaction, the fuel uses the chemical energy released during the reaction of hydrogen and oxygen to produce water and to produce carbon dioxide using carbon monoxide and oxygen.

High-temperature fuel cells also produce high-
energy products that can be used to combine heat and power in low-cost processes.

High-
temperature fuel cells can be made easily and efficiently without expensive metal catalysts such as platinum. On the other hand, the energy released by the electrochemical reaction decreases as the reaction temperature increases.

High temperature fuel cells face serious problems. Few materials can work for a long time without deteriorating in a hot chemical environment. Also, hot work is not suitable for large-
scale work and situations that need to be started quickly. Therefore, the current high-temperature fuel cell application mainly focuses on power stations where the internal modification and compression efficiency is more than low-end product and slow start-up.

The best known fuel cells are:

- Molten Carbonate
- Solid Oxide

Low temperature fuels generally operate below 250 ºC (480 ºF). These low temperatures do not allow internal reforming, so an external hydrogen source is needed.

On the other hand, they start fast, have fewer equipment problems, and solve vehicle handling problems more easily.

The most important low temperature fuel cells are:

- Alkali
- Phosphoric acid

- Proton exchange membrane (or solid polymer)

PEM Fuel Cell Performance

Figure 11: PEM fuel cell

Efficiency

The performance of fuel cells is often considered one of the key benefits of the technology. While this is true in principle, it is important to distinguish between fuel cell stack efficiency and fuel cell system efficiency.

Fuel Cell Stack Efficiency

Fuel cell batch efficiency is mainly related to the accuracy of the electrochemical reaction. This performance can be given as follows. According to the $H_2 + ½O_2$ H_2O reaction, the energy released when hydrogen and oxygen come together to form water is considered the "reaction enthalpy" (ΔH^0). This value is measured experimentally and depends on whether the water is gaseous or liquid. For gas cells where water is formed in gaseous state, the reaction enthalpy is called:

$$\Delta H^0_{(gas)} = -230 \frac{BTU}{mole_{Water}} = -242 \frac{kJ}{mole_{Water}}$$

Where $mole_{water} = 6.023 \times 10^{23}$ water molecules
the energy released during the reaction is not absorbed.

The enthalpy of this reaction is definitely only 77 ºF (25 ºC) and 1 air pressure. The effect of temperature is greater than the effect of altitude, and the power output decreases with temperature. Change in energy efficiency changes only a few percent the the with the heat. Therefore, high-temperature fuel is less powerful than low-temperature fuel.

Unfortunately, not all of the enthalpy of a reaction can be used to do important work. Some of the enthalpy in the form of entropy causes disorder of the world and disappears; the remainder is called the "Gibbs free energy" (ΔG0). For gaseous water (77 ºF / 25 ºC and 1 air), it is known:

$$\Delta G^0_{(gas)} = -217 \frac{BTU}{mole_{Water}} = -229 \frac{kJ}{mole_{Water}}$$

The voltage of a cell ($\mathcal{E}_{Cell}$) is related to the Gibbs free energy according to the following equation:

$$\mathcal{E}_{Cell} = -\frac{\Delta G^0}{n\mathcal{F}}$$

Where n = number Number of electrons involved in the Reaction. The simplest expression is "moles of electrons", $\boldsymbol{\mathcal{F}}$ = Faraday's constant.

Turn the results into equations (using British units):

$$\mathcal{E}_{Cell} = \frac{-217\ \cancel{BTU}}{\cancel{mole_{Water}}}\ x\ \frac{1055.7\ J}{\cancel{BTU}}\ x\ \frac{\cancel{mole_{Water}}}{2\ \cancel{mole\ e^-}}\ x\ \frac{\cancel{mole\ e^-}}{95{,}500\ coul}$$

$$= \frac{1.187\ J}{coul} = 1.187\ V$$

Therefore, each cell can produce a maximum theoretical voltage of 1.187 V (at 77 ºF / 25 °C and 1 air). Fuel cell efficiency is therefore the ratio of the actual voltage produced by the cell to the theoretical maximum:

$$Efficiency\mathcal{E}_{Cell} = \frac{V_{Actual}}{\mathcal{E}_{Cell}} \cong \frac{V_{Actual}}{1.2\ V}$$

For a true fuel cell, typical voltages at normal operating other loads are between 0.5 and 0.6 V and can reach 1.1 of normal operating loads. . V open state. Therefore, the electrochemical efficiency is usually around 40% to 50%, up to 90% under open circuit conditions.

Fuel Cell System Efficiency

The efficiency of the fuel cell system is related to the overall efficiency of the fuel cell power plant.

The fuel cell assembly can only work if it is fed with compressed air and hydrogen and rinsed with cold water. Oil-
fired power plants require additional equipment to control oil and fluid flow, lubrication, service operations, control electrical equipment, and provide process control. Some machines contain modifiers to treat the oil. All of these devices create losses and reduce the optimum performance of the body.

In order to make a good comparison between fuel cells and other generators, all generators must be defined in the same way.

When comparing gas generators to internal generators for automotive use, they can easily be defined as devices that access gas and air and provide electricity to equipment to power the driver. In both cases, oil is taken from tanks in gaseous or liquid form and stored after refining or other processing.

Two air compressors; Internal combustion engines use only pistons, while fuel cell engines use an external combustion engine. The internal combustion engine supplies electricity directly to the engine, while the internal combustion engine uses an electric motor and an electric motor. Both systems use coolant pumps, electric motors and other thermal management systems to dissipate heat to the environment. Both machines share the same truckload.

The overall efficiency of the internal combustion engine is usually between 15% and 25%. These values
represent the performance of the car's wheels; Flywheel output is usually between 30% and 35% efficient and more for diesel engines.

For a pure hydrogen fuel cell power plant, the comparison of the efficiency of the flywheel output is approximately as follows:

Fuel cell efficiency: 40 - 50%

Air compression: 85% (using 15%) % of total power' si)

Inverter Efficiency: 95%

Motor Efficiency: 97%

The multiplication of each of these values
yields a full system efficiency of approximately 31 to 39%.

For fuel cells operating with a modifier, these efficiencies are further reduced from 65% to 75% for all processes, from about 20% to 29% (depending on the type of modifier).

The effect of total weight is more difficult to measure. Fuel cell systems (including fuel storage) are heavier than hybrid generators of the same power and range and therefore use more electricity.

Electrochemical battery is better compared to fuel cell. While the battery does not need air compression, cooling equipment or converters when used as an electric motor in a car, it also needs generators and generators. Batteries with energy storage are heavier than fuel cells, but this is somewhat offset by the removal of other components.

Taking a step back, fuel products have become an integral part of the overall operation.

For internal combustion engines this often includes refining hydrocarbon fuels. For fuel cells, this includes the production of hydrogen from fossil fuels or the electrolysis of water, or the production of fuels such as methanol for reformers. For battery systems, this includes the energy used for charging.

These conditions are difficult to analyze and depend on the location of the oil, the method of operation, handling and transportation difficulties, and other factors such as the energy required to compress or liquefy the oil. Ultimately, these conditions reduce the overall cost of oil; however, this cost may not include costs associated with long-term environmental damage.

Polarization Characteristics

Ideally, the theoretical optimum fuel cell voltage of 1.2 V is reached at all operating currents. Fuel cells reach their maximum output voltage in open circuit (no load) conditions and current is drawn with voltage drop. This is called polarization and is represented by a polarization curve as shown in Figure 12.

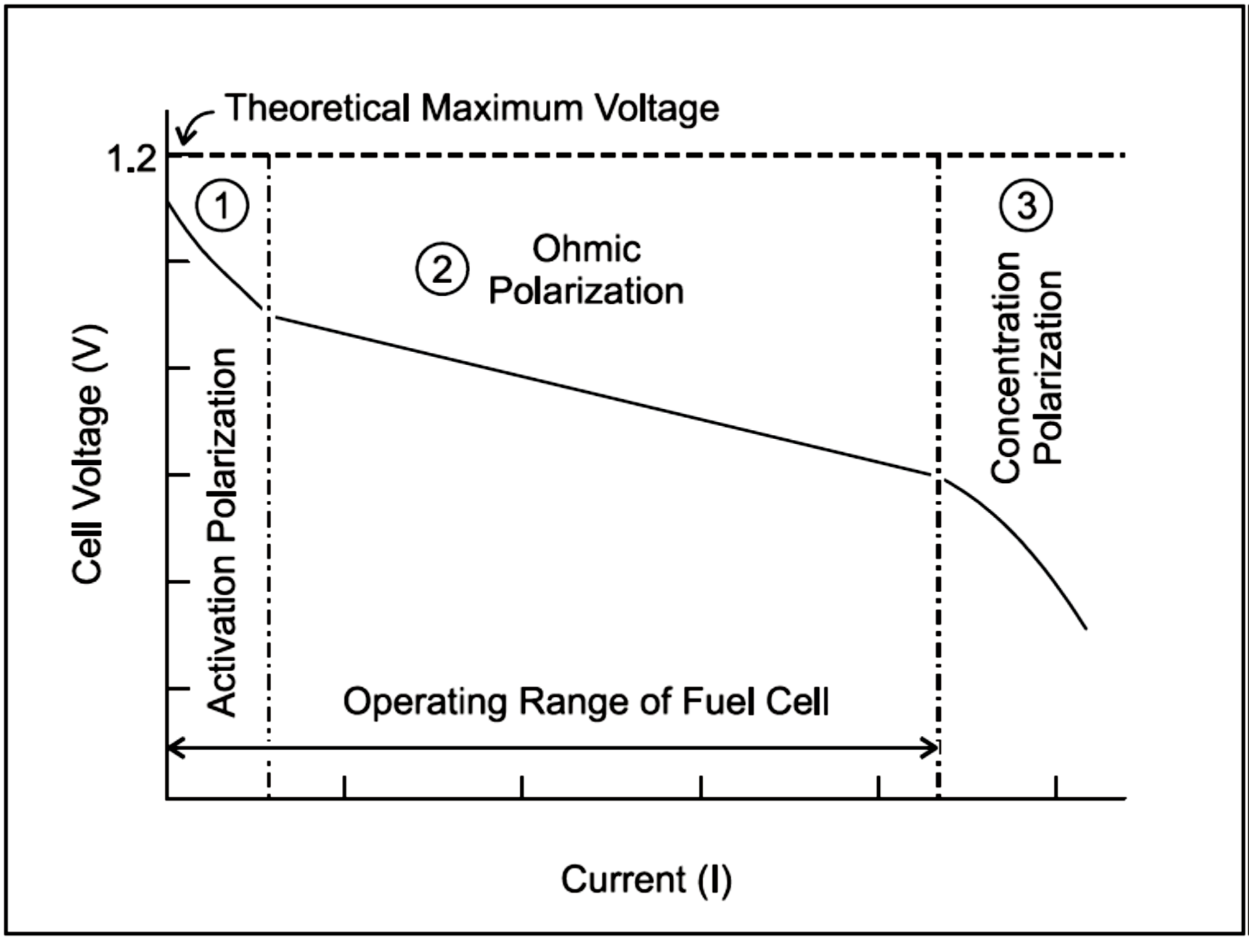

Fig. 12: Typical PEM fuel cell polarization curve

The polarization curve shows that the cell's hand is defined as the current work. Now it depends on the size of the electric charge of the fuel cell respectively. More importantly, the polarization curve shows the electrochemical efficiency of the fuel cell at its operating current, since the efficiency is the ratio of the actual cell voltage divided by the theoretical maximum of 1.2 V.

The polarization curve of the battery is similar to this. from the fuel cell. Both batteries and fuel cells have the best performance, as the voltage increases as the load decreases.

In contrast, internal combustion engines operate efficiently at full load and quickly lose efficiency at part load.

Polarization results from chemical and physical effects on many aspects of the fuel cell.

These conditions limit the chemical reaction process as current flows. Three main factors affecting the polarization of the Earth:

- Increased polarization
- Ohmic polarization (or resistance polarization)
- Concentration polarization

The difference of cell potential from positive behavior is the result of the number of these factors that directly affect the total charge.

Activation Polarization

Polarization relates to the energy barrier that must be overcome to initiate a chemical reaction of reactants. When there is less current consumption, the electricity rate changes gradually, and some of the electricity is lost to compensate for the lack of electrocatalytic activity.

Ohmic Polarization

Ohmic polarization (or "resistive polarization") occurs due to low voltage in the battery. These losses occur in the electrolyte (ions), electrodes (electrons and ions), and terminals (electrons) in the battery. Since the stacked plate and electrolyte obey Ohm's law (V = IR), the amount of voltage drop in the field varies with the region.

Concentration Polarization

Concentration polarization occurs when the reaction electrode is affected by a mass change. In this region, reactants are consumed faster than they are given, while products accumulate faster than they are removed. Eventually these effects inhibit all other reactions and the cell voltage drops to zero.

Power Characteristics

Electricity is the product of voltage and current (P = VI). Since the polarization curve of the fuel cell shows the relationship between voltage and current under all operating conditions, it can be used to provide the energy curve. The current at any point on the curve is represented as a rectangle touching the curve. Figure 13 shows a power curve.

Maximum power occurs between 0.5 and 0.6 V, which corresponds to a very high current. At its peak, the internal resistance of the battery is equal to the resistance of the external circuit. However, there is a trade-off between high power and high efficiency because efficiency decreases with increasing voltage. Electrical power generators must select the desired performance based on whether efficiency or power is important to the application. He never wanted to cross the falling power curve.

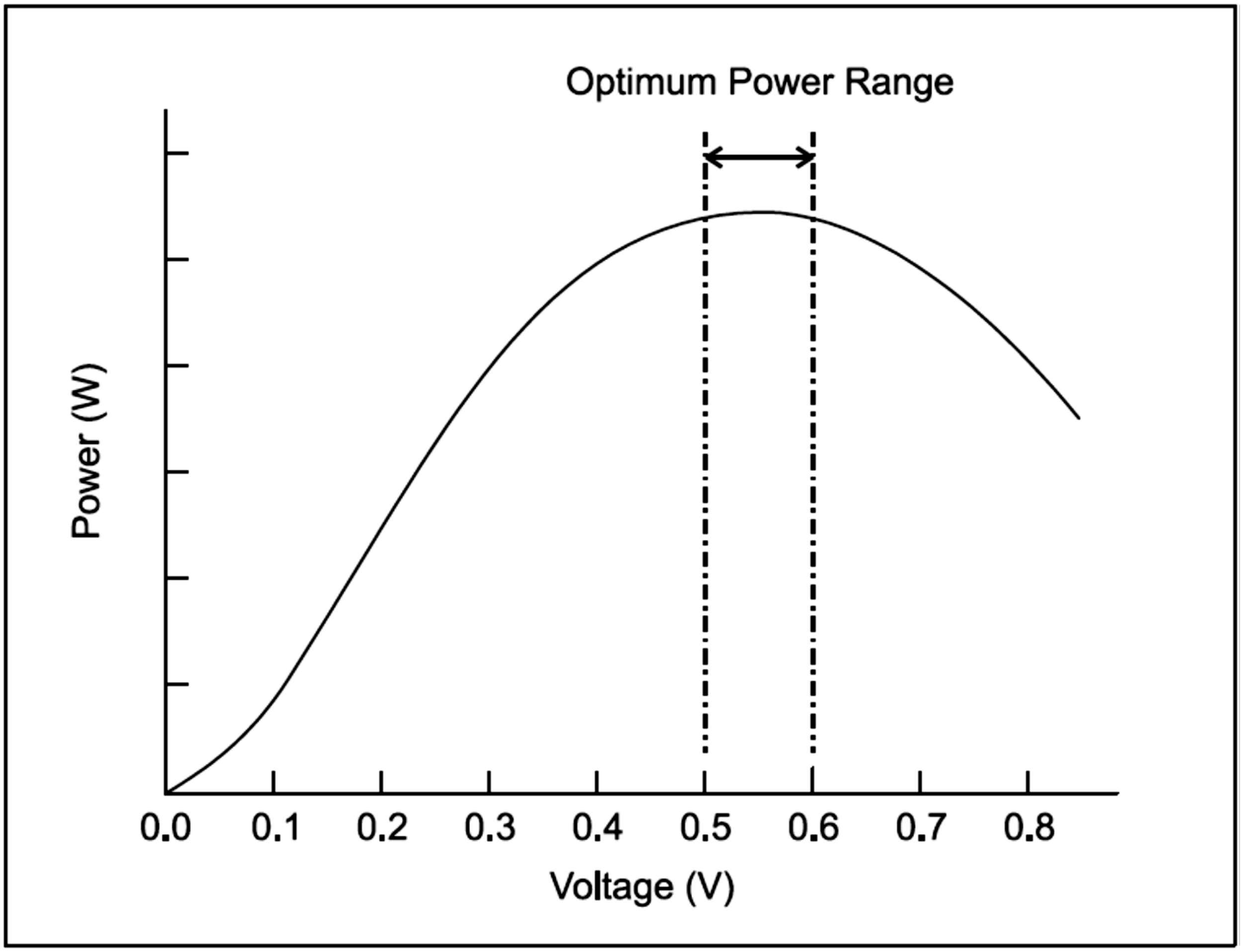

Fig. 13: Typical PEM fuel cell power curve

Temperature and Pressure Effects

The shape of the polarization curve depends on the operating temperature and pressure of the group. In general, a series of polarization curves can be drawn to characterize the performance of the battery pack over the entire operating range.

Fuel cell designers evaluate the overall performance of a fuel cell assembly in terms of volumetric energy density. It is calculated by dividing the maximum energy in W/L by the body volume. Energy density indicates that a small unit can break a lot of energy.

PEM fuel cells have a power density of over 1350 W/L; Ten years ago the power density was about 90 W/L.

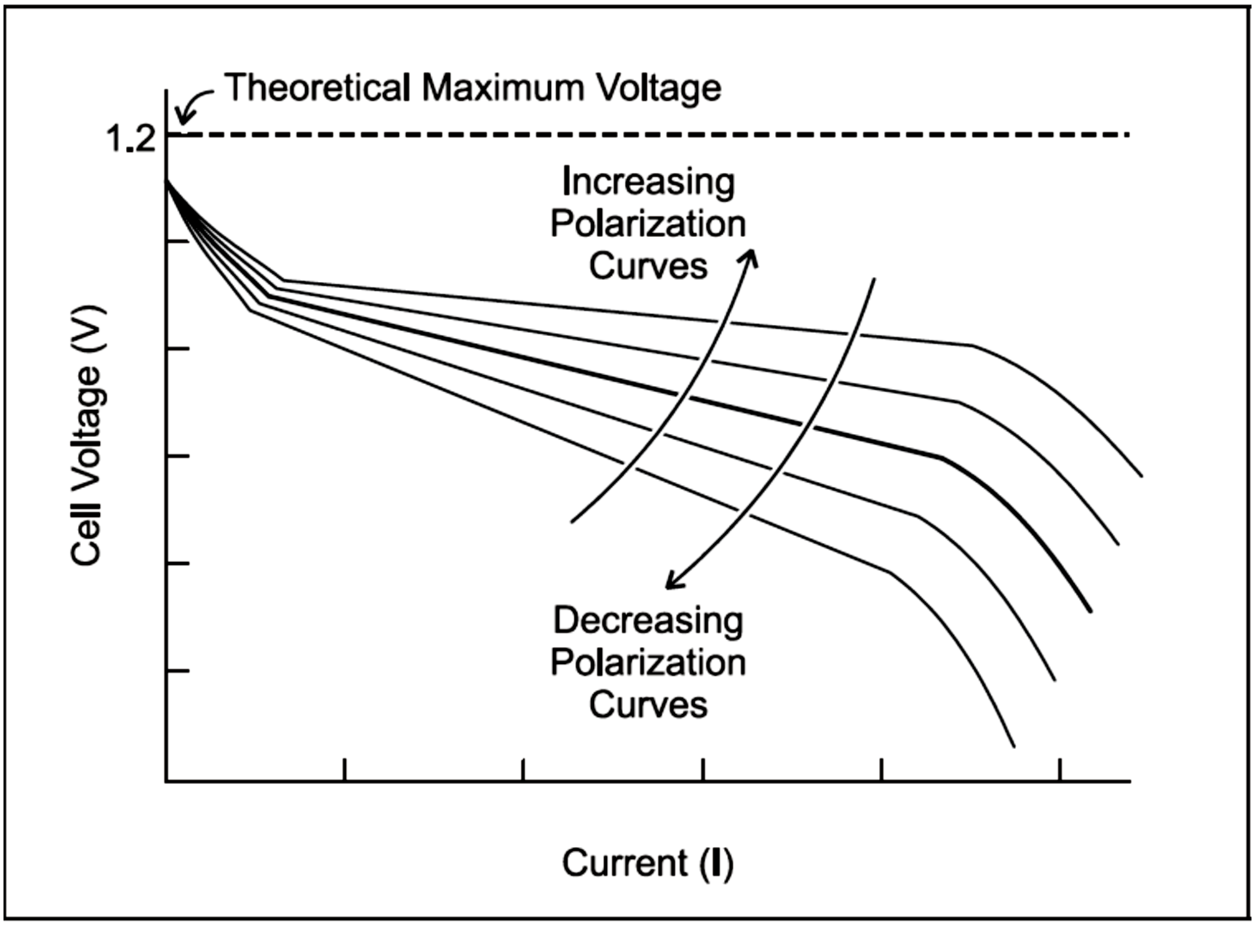

Fig. 14: Polarization curve change

In general, the change is such that it becomes more and more powerful. electrochemical efficiency. back.

Pressure

The fuel cell polarization curve usually increases with higher performance. On the contrary, the polarization curve decreases with higher activity.

This is because the reaction rate is directly proportional to the partial pressure of hydrogen and oxygen. (All gases in the fuel mixture contribute to a partial pressure equal to the total pressure.) Therefore, the result of the maximum pressure increase is expressed when either dilute oxidant (eg air) or dilute oil (eg modified) is used. .

Essentially, the higher pressure helps hydrogen and oxygen come into contact with the electrolyte. Pressure sensitivity is greater at high tides.

Although the increase in pressure encourages the electrochemical reaction, it also brings other problems. Fuel cell bulk flow fields work better at low pressure because they show less shock. Fuel cell seals operate under increased pressure. There must be more air compression that draws all the power. Other processes need to be reinvented; For this reason, some products need to be increased in size and price.

Ultimately, high pressure restores low pressure, given the performance of the group and the overall effect of the body. Because of these factors, PEM fuel cells generally operate at altitudes of no more than a few atmospheres.

Temperature

The fuel cell polarization curve increases with increasing operating temperature. On the contrary, the polarization curve decreases as the operating temperature decreases.

This is because high temperature improves mass transfer in the gas and causes a decrease in the cell (electron conduction decreases in metal as temperature increases, but ionic conductivity increases in electrolytes). Together, these effects increase the reac tion.

Water build-
up in the oxidant stream effectively limits the operating temperature to below 212 ºF (100 ºC). Water boils in heat and cold, and the resulting steam reduces some of the oxygen. This greatly reduces the performance of the battery due to lack of oxygen. This can damage the fuel cell and shorten its life.

Because the connection increases the temperature of the water, higher temperatures can be achieved by operating at partially higher altitudes. However, this effect is small in high efficiency PEM fuel cell operation.

As a result, the electric current of the gas increases with the temperature until the temperature reaches the temperature of the hot water, while the electric current begins to decrease. The optimum temperature is around 175 °F (80 °C), where the two effects are equal, as shown in figure 15. Operating temperature is 158 to 194 °F (70 to 90 °C).

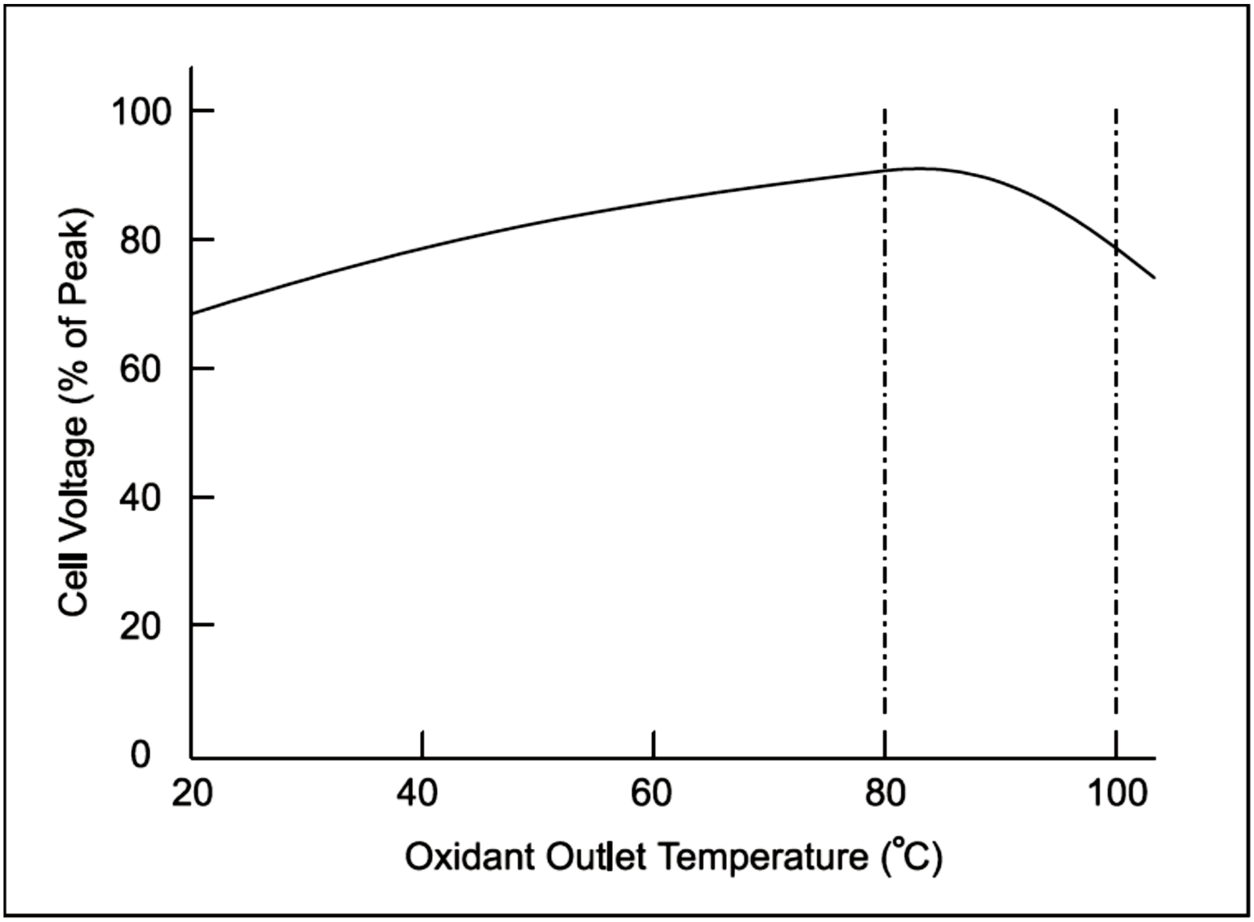

Figure 15: Effect of temperature on fuel cell voltage

According to high voltage operation, high temperature operation affects all components in the system, some need to be adjusted accordingly.

Stoichiometry Effects

Fuel Cell Polarization Curves Increasing Gas Stoichiometry with Reagents. Conversely, the polarization curves decrease as the reactant gas stoichiometry decreases.

This is because the larger stoichiometry causes more hydrogen and oxygen molecules to interact with the electrolyte. Insufficient stoichiometry can cause the fuel cell to lose (or "starve") enough nutrients and cause permanent damage.

Stoichiometry is the ratio of the gas available to the gas required to complete the reaction. This is similar to the concept of gravity, where density corresponds to the material used. Therefore, a stoichiometric ratio of 1.0 gives the exact number of gas molecules required for the reaction to theoretically complete. A stoichiometric ratio greater than 1.0 gives too much fuel, while a stoichiometric ratio less than 1.0 gives insufficient fuel. A stoichiometric ratio of 2.0 gives twice the number of gas molecules needed.

As the gas flow stoichiometric ratio increases, the resulting fuel gas temperature gradually reaches the terminal voltage as shown in Figure 16. Product electric power generators generally operate with a hydrogen stoichiometry of 1.4 and an air stoichiometry of 2.0 at rated load; added oil provides little added benefit. A larger stoichiometric ratio is required when operating at low power.

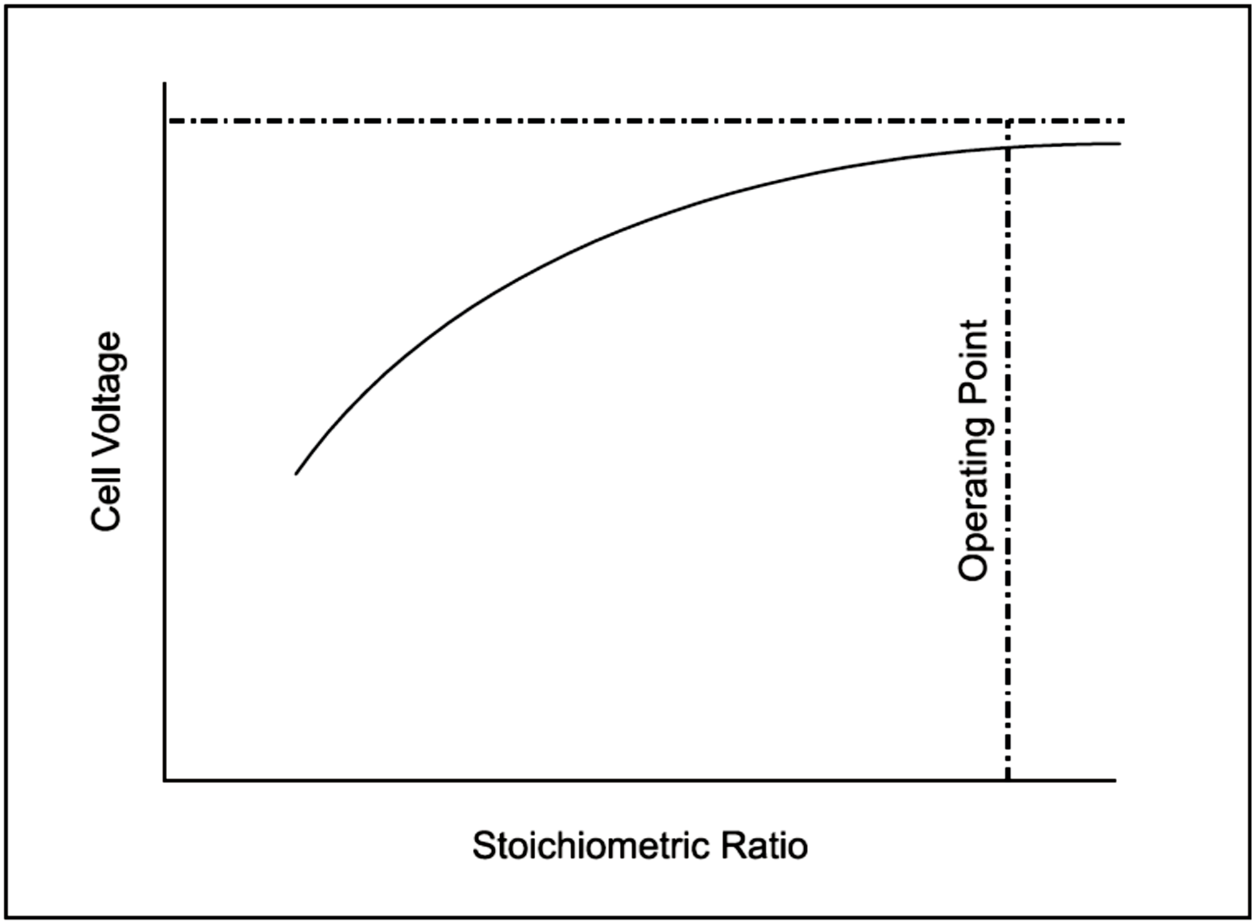

Figure 16: Effect of stoichiometry on fuel cell voltage

Humidity Effects

Adequate air generation is important for PEM fuel cell operation because water molecules move with hydrogen ions during the ion phase change.

Dehydration can cause dehydration and cause cracks or holes in membranes. This can cause short-
term chemical reactions, local fuel mixing, hot spots and the possibility of fire.

On the contrary, over-
humidification will cause voids to form and migrate to the flow plate. This causes a phenomenon called "battery reversal", in which the battery reacts to produce a zero or

negative voltage. If there is enough negative current, the affected gas begins to act as an electrolyte. This generates a lot of heat and can damage the battery. A battery monitoring system is often installed to check battery charge before battery damage occurs.

Humidity is usually measured as "relative humidity"; relative, because it depends on the pressure and temperature of the gas. When the oil absorbs as much water as it can absorb at this pressure and temperature, it is considered saturated and its moisture content is 100%. If the saturated fat gets hot (without adding more water), the relative humidity will drop. (The relative humidity drops by about 4 percent at each temperature) If the oil cools, some of the water condenses and the oil remains saturated at that temperature.

Fuel cells generally operate at or near the saturation point of the fuel's operating temperature (determined by the coolant). This ensures maximum water retention while preventing flooding.

Using water for good humidity avoids fuel use and keeps the temperature between 32 and 212 ºF (0 to 100 ºC). Beyond these limits ice and boiling occur, respectively.

Another issue is that the humidifier must remain without electricity. Failure can cause short circuit and corrosion current in the fuel cell stack. Water becomes active when it receives ions from its surroundings. To remove these ions, water must flow continuously through the deionization filter.